PHILCO

A Subsidiary of Ford Motor Company

LANSDALE DIVISION
Lansdale, Pennsylvania

PEM for
GOLD-DOPED GERMANIUM
INFRARED DETECTOR TYPE IR400
Second Quarterly Progress Report
27 March 1963 to 27 June 1963

Contract No. DA-36-039-AMC-04164(E)
Order No. 21039-PP-63-81-81
Placed by USAEMA, Philadelphia, Pa.

PHILCO
Ford Motor Company

LANSDALE DIVISION
Lansdale, Pennsylvania

PEM for
GOLD-DOPED GERMANIUM
INFRARED DETECTOR TYPE IR400
Second Quarterly Progress Report
27 March 1963 to 27 June 1963

Contract No. DA-36-039-AMC-04164(E)
Order No. 21039-PP-63-81-81
Placed by USAEMA. Philadelphia, Pa.

PHILCO CORPORATION

LANSDALE DIVISION

Lansdale, Pennsylvania

PEM for
GOLD-DOPED GERMANIUM
INFRARED DETECTOR TYPE IR400
Second Quarterly Progress Report
27 March 1963 to 27 June 1963

Contract No. DA-36-039-AMC-04164(E)
Order No. 21039-PP-63-81-81
Placed by USAEMA, Philadelphia, Pa.

Philco Project No. H-200

PHILCO CORPORATION
LANSDALE DIVISION
Lansdale, Pennsylvania

PEM for GOLD-DOPED GERMANIUM INFRARED DETECTOR TYPE IR400

Second Quarterly Progress Report

Period Covered:

27 March 1963 to 27 June 1963

Contract No. DA-36-039-AMC-01464(E)

Order No. 21039-PP-63-81-81

Placed by USAEMA, Philadelphia, Pa.

Object of Study:

Production Engineering Measure (PEM) in accordance with Step I of Signal Corps Industrial Preparedness Procurement Requirements (SCIPPR) No. 15, dated 1 October 1958, for p-type, gold-doped germanium infrared detector, Form 2 per Specification SCS - 36A, dated 8 April 1960. Work includes establishing a pilot line to manufacture the detector, demonstrating the capability to fabricate and test 15 units meeting applicable specifications per 8-hour shift.

Philco Project No. H-200

Report prepared by D. Skvarna and R. J. Roode

TABLE OF CONTENTS

SECTION I - ABSTRACT

The reported work is on a PEM for producing p-type gold-doped germanium infrared detectors, Type IR400.

The report covers the second quarter of the contract period. The work for the period is divided into three main categories: gold-doped germanium crystal growing, material evaluation and testing, and barium fluoride transmission window sealing to glass.

The procedures involved in material and device fabrication and testing are discussed. Evaluation data is included in tabular and graphic form.

Problems encountered in device fabrication and testing and difficulties experienced in the barium fluoride sealing program are also discussed.

SECTION II - PURPOSE

The purpose of this Production Engineering Measure is to develop and demonstrate production facilities capable of producing p-type, gold-doped germanium infrared detectors. The detectors shall be Form 2 per Specification SCS-36A, dated 8 April 1960. The production capability to be demonstrated on a pilot line basis shall be equipped to manufacture and test 15 units meeting applicable specifications per 8-hour shift. A production type run of 50 units is to be performed to demonstrate the specified capability.

Performance of the contract also calls for furnishing of the following:

1. Engineering samples (6 each)
2. Preproduction samples (12 each)
3. Special tooling consisting of:
    a. Copper-Kovar Multi-unit Bonding Fixture
    b. Special Coil for R-F Bomber
    c. Special Chamber for R-F Bomber
    d. Variable Speed Chopper (100 cps to 40 kc)
    e. Exposure Test Console
4. Quarterly Reports (30 copies/quarter)
5. Final Engineering Report (30 copies)

6. Bills of Materials and Parts (2 copies)
   (Forms DD-346 and DD-347)

7. General Report on Step II (6 copies)
   (Covering a rate of 50 p-type, gold-doped germanium infrared detectors meeting the applicable specifications per 8-hour shift).

SECTION III - NARRATIVE AND DATA

3.0 Introduction

Effort was concentrated on gold-doped germanium metallurgy and barium fluoride window sealing during this quarter. Gold-doped germanium of varying characteristics was prepared and characterized, and devices were fabricated and evaluated. Barium fluoride window seals were made and tested.

3.1 Metallurgical Program

3.1.1 General Objectives

The metallurgical program for specification and production of high detectivity material has as its objectives:

a. Optimization of gold concentration in the germanium,

b. Perfection of crystal structure necessary to accommodate the optimum gold concentration,

c. Optimization of compensation concentration,

d. Production of the desired material reproducibly and with high yield.

3.1.2 Approach

In order to evaluate the gold-doped germanium from the standpoint of infrared detection, a range of resistivities, carrier concentrations and crystal perfection is required. This range of resistivities, concentrations, and crystal perfection is most easily obtained by selecting zones from a vertically pulled ingot (Czochralski method). The selected zones are characterized by parameter measurements and fabricated into infrared detectors. The primary parameter in evaluation is the detectivity (D*).

The evaluation data will permit selection of the optimum detector material, following which zone leveling techniques will be used to reproduce optimum material on a larger scale.

3.1.3 Source of Polycrystalline Material

Intrinsic, polycrystalline material of the highest purity attainable was purchased from three different suppliers. No significant difference in either doped single-crystal characteristics or detector performance could be traced to source material.

3.1.4 Preparation of Polycrystalline Material

Material is made ready for growth of doped single crystals by etching in a 3 to 1 solution of HNO_3/HF acids, rinsing in deionized water and drying with an infrared lamp.

The quartzware, which includes the furnace tubes, crucibles and boats, is prepared by washing in a solution which is 70% HNO_3 and 30% HF by volume, rinsing in deionized water and drying with an infrared lamp. The boat for zone leveling is coated with a layer of silicon dioxide to prevent spurious nucleation.

3.1.5 Characterization of Doped Single-Crystal Material

Each ingot grown is characterized by the following parameters, determined by cutting and making measurements on sample wafers.

a. Room temperature resitivity profiles.

b. Room temperature mobility.

c. Net carrier concentrations at room temperature.

d. Dislocation densities revealed by etch pit counts.

e. Cooling ratios which are ratios of resistivity at $78^\circ K$ to resistivity at $300^\circ K$.

3.1.6 Material Prepared and Evaluation

During the second quarter, two Czochralski and six zone leveled ingots of compensated gold-doped germanium were made. A brief description of the ingots evaluated is given below and data is tabulated in the Appendix.

Crystal B125

The polycrystalline material was given 16 zone refining passes before pulling an uncompensated single crystal by the Czochralski method. Parameter measurements are given in detail in Table 1 and summarized below.

Parameter	Range
Resistivity, ohm-cm	1.25 to 4.25
Mobility, cm^2/volt sec	2600 to 3100
Net carrier concentration, no./cm^3 x 10^{15}	1.07 to 1.69
Dislocation density, pits/cm^2	5250 to 8150
Cooling ratios	61,000 to 110,000

The results of evaluation by measurements on detectors are summarized below and given in detail in Table 2 and Figure 1.

Measurement	Range
D*, $\frac{cm(cps)^{1/2}}{watt} \times 10^9$	0.70 to 1.70
Detector resistance at 77°K, ohms x 10^3	77 to 280
Bias current, microamperes	36 to 450

Crystal B128

The polycrystalline material was given 25 zone refining passes prior to pulling a single crystal, compensated with 1 x 10^{14} atoms/cc of Sb, by the Czochralski method. Parameter measurements are given in detail in Table 3 and summarized below.

Parameter	Range
Resistivity, ohm-cm	0.20 to 2.3
Mobility, cm^2/volt sec	2500 to 2880
Net carrier concentration, no./cm^3 x 10^{15}	1.3 to 3.0
Dislocation density, pits/cm^2	11,800 to >14,000
Cooling ratios	100,000 to 274,000

The results of evaluation by measurements on detectors are given in detail in Table 4 and Figure 2 and summarized below.

Measurement	Range
D*, $\frac{cm(cps)^{1/2}}{watt}$ x 10^9	0.95 to 1.80
Detector resistance at 77°K, ohms x 10^3	240 to 600
Bias current, microamperes	53 to 430

Crystal B129

The polycrystalline material was not zone refined prior to pulling a single crystal, compensated with 1 x 10^{14} atoms/cc of antimony, by the Czochralski method. Parameter measurements are given in detail in Table 5 and summarized below.

Parameter	Range
Resistivity, ohm-cm	0.56 to 2.44
Mobility, cm^2/volt sec	2690 to 2800
Net carrier concentration, no./cm^3 x 10^{15}	1.0 to 1.5
Dislocation density, pits/cm^2	5450 to >9,900
Cooling ratios	65,000 to 210,000

The results of evaluations by measurements on detectors are given in detail in Table 6 and Figure 3 and summarized below.

Measurement	Range
D*, $\frac{cm(cps)^{1/2}}{watt} \times 10^9$	0.92 to 2.50
Detector resistance at 77°K, ohms x 10^3	140 to 400
Bias current, microamperes	53 to 410

Crystal B139

The polycrystalline material was not zone refined prior to pulling a single crystal, compensated with 1×10^{14} atoms/cc of antimony, by the Czochralski method. Parameter measurements are given in detail in Table 7 and summarized below.

Parameter	Range
Resistivity, ohm-cm	1.05 to 3.86
Mobility, cm^2/volt sec	2390 to 2760
Net carrier concentration, no./cm^3 x 10^{15}	0.76 to 2.33
Dislocation density, pits/cm^2	5200 to >11,600
Cooling ratios	21,000 to 82,000

The results of evaluation by measurements on detectors are given in detail in Table 8 and Figure 4 and summarized below.

Measurement	Range
D*, $\frac{\text{cm(cps)}^{1/2}}{\text{watt}} \times 10^9$	1.28 to 2.08
Detector resistance at 77°K, ohms x 10^3	110 to 160
Bias current, microamperes	38 to 340

Evaluation of crystals B141, BF146, BF147, BF147A, BF148, BF149A and BF150 is not complete. They will be discussed in the next quarterly report.

3.2 Detector Fabrication and Testing

3.2.1 Parts, Fixtures and Jigs

During this report period, the following parts, designed in the first report period, were built or purchased and used:

a. Carbon boats for indium alloy contacts

b. Gold plated kovar tabs for contacts to the germanium element

c. Test cell mounts of kovar

d. A prototype of an improved evaluation dewar

e. Silver ring for sealing barium fluoride to glass.

3.2.2 Detector Processing

The ingots are sliced with a diamond saw into wafers 0.100" thick, and are approximately 0.75" in diameter. The wafers are then cut into bars 0.100" x 0.100" x 0.400". The bars are

reduced in dimension by machine lapping to 0.90" x 0.90" x 0.375". The detector size selected as optimum for fabrication is 0.08" x 0.08" x 0.375".

The germanium bar is etched for two minutes in CP4 (hydrofluoric acid, nitric acid, acetic acid, and bromine) at 27°C. The material removal rate of this etch is about 0.001" per minute. After the bar has been etched and rinsed in deionized water, it is sandwiched between indium-tinned kovar tabs and placed in a carbon alloying boat. The assembly is made a unit by alloying in a hydrogen atmosphere at 400°C for two minutes. Platinum leads are soldered to the unit and the unit is placed into a demountable dewar that is fitted with a silicon window, and evacuated to a pressure of 15 microns.

3.2.3 Detector Testing

The unit is tested in a test set which uses a 500°K black body as a source of radiation. The variation of signal to noise ratio with bias current is recorded and D* is calculated for the best value of signal to noise ratio determined.

3.2.4 Problems and Solutions

a. It was previously reported that the alloying fixture in use did not provide constant pressure to the kovar tabs

during the alloying process, and noisy contacts resulted. Figure 5 shows the carbon alloy boat which has been used during the second quarter to make indium-germanium alloyed contacts. These contacts are much more uniform and the noise is lower.

b. Figure 6 shows the demountable test dewar in use during the second quarter. It uses a kovar cell mount instead of copper. This reduces the possibility of contaminated surfaces through etching.

c. In the present method of preliminary testing of the detector element, the unit is mounted onto the kovar cell mount in a demountable dewar. This presents a problem in evaluation, since the forepump vacuum of the demountable dewar does not provide good thermal insulation, resulting in high temperatures of the detecting element and, consequently, a low D*. The test dewar illustrated in Figure 4 of the First Quarterly Report has been constructed to provide better cooling of the detector element, and preliminary tests have shown that cell noise measured in the proposed test dewar is too high. More experiments will be conducted in an attempt to reduce cell noise to the proper value so that this method of testing detector elements may be used.

If use of the proposed test dewar is possible, interpretations of test results will not require extrapolation to liquid nitrogen temperature, as it does now, since the detector element will be at liquid nitrogen temperature during measurement.

3.3 Transmission Window Investigation

3.3.1 General

The selection of window material is influenced by several factors, such as

a. Transmittance

b. Cost

c. Durability under environmental conditions of temperature, vibration, humidity, pressure, etc.

d. Good properties under vacuum

e. Ability to provide reliable seals to glass or metal.

Barium fluoride exhibits superior transmittance to 9.5 microns, resulting in enhanced detectivity of any detector operating within this spectral region. Furthermore, its low reflective loss eliminates the need for anti-reflective coatings. Another advantage is the transmission in the visible portion of the spectrum, allowing visual alignment of optics. While these

advantages make barium fluoride attractive. this material is generally avoided in windows due to its softness, water solubility, and high coefficient of thermal expansion.

It has been determined experimentally that an increase of detectivity of 25 - 30% can be expected by the use of a barium fluoride window as opposed to a silicon window.

3.3.2 Barium Fluoride Sealing Program

Barium fluoride windows have been successfully sealed to glass using silver chloride and a silver ring. Figure 7 shows the assembly of a barium fluoride seal and a completed seal. These seals have been environmentally tested and some of the sealed windows have withstood the temperature cycling tests of MIL-STD-202B - Method 102, Test Condition D. However, the real test of the seal is environmental testing of a barium fluoride window on a completed detector, and a decision on the feasibility of a barium fluoride window cannot be made until such tests are conducted.

SECTION IV - CONCLUSIONS

The metallurgical and material evaluation program is progressing satisfactorily. An estimated 30% of the program has been accomplished by the end of the second quarter.

Vacuum tight barium fluoride window seals to glass have been made. The seals are now being subjected to environmental tests and a decision on the feasibility of a barium fluoride window will be made when these tests are completed.

SECTION V - PROGRAM FOR THE NEXT INTERVAL

1. Complete metallurgy studies.
2. Determine material specifications.
3. Evaluate barium fluoride seals with environmental tests.
4. Design environmental exposure test console.
5. Design variable speed chopper.
6. Fabricate and test three engineering samples.

SECTION VI - PUBLICATIONS, REPORTS AND CONFERENCES

No publications, lectures, or reports pertaining to work developed on this contract were issued or given during the period covered by this report.

One conference pertaining to this contract was held during the quarter covered by this report. The conference was held on 18 April 1963 at the facilities of the Philco Corporation, Lansdale Division, in Lansdale, Pennsylvania, with representatives of the USAEMA and of the Philco Corporation in attendance.

SECTION VII - IDENTIFICATION OF PERSONNEL

The key technical personnel who have taken part in the work covered by this report are listed below and the approximate man-hour figures are also given for three general categories of technical assistance furnished to the key personnel during the quarter. A background resume of a key technical individual added to the program during the second quarter is included.

Name		Approx. Man-hours
Cohen, B.		102
Devito, L.		43
Dunkle, R.		50
Peterson, A.		150
Roode, R.		60
Skvarna, D.		364
Snyder, C.		160
	Total	929
Misc. Engineering		60
Technicians and Operators		700
Draftsmen and Model Makers		20

Roode, Ralph J.

Mr. Roode received his B.Sc. in Physics from Washington and Jefferson College and his M.Sc. in Physics from Ohio State University.

He has had experience in low temperature physics, physical electronics, electronic circuit design, high and ultrahigh vacuum technology and solid state physics. At the Martin Company, Baltimore, Md., he was responsible for the development of equipment and techniques for evaluation of infrared detector materials and evaluation of completed doped germanium infrared detectors. Also, he participated in the development of such detectors and was responsible for the development of an indium antimonide photoelectromagnetic detector, the first infrared detector made at the Martin Company.

At Philco he is responsible for development of photoconductive indium antimonide, gold-doped germanium and mercury-doped germanium detectors. He is also responsible for establishing new or refining old techniques for characterizing quantitatively the devices made by the Infrared Department of the Special Products Operation at Philco.

Mr. Roode is a member of the IEEE, the IEEE Professional Technical Group on Electron Devices, the American Physical Society, the Solid State Group of the APS, and Sigma Pi Sigma, a national physics honor society.

APPENDIX - TABLES AND FIGURES

Table 1

PARAMETER MEASUREMENTS - INGOT NO. B125

Supplier: Amer. Metals
Ingot Wt: 350 g
Dopant Amounts: Au 3 g

No. of Passes: 16
Avg. Resistivity: 40 ohm-cm

Date: 5/14/63
Orientation: <111>

Wafer No. →		1	6	11	16	21
ρ at 300°K ohm-cm	1	3.52	2.94	2.06	1.88	1.31
	2	4.24	2.53	1.97	1.72	1.26
	M	2.62	2.34	1.99	1.69	1.25
	3	3.04	2.60	2.12	1.88	1.28
	4					
Dislocation Density no./cm^2 x 10^3		5.25	7.75	8.85	8.15	very high
Cooling Ratios x 10^3	1	74	83	83	83	61
	2	76	--	89	107	--
Hall Measurements at 300°K						
ρ ohm-cm		2.65	2.34	1.88	1.73	1.20
R_H cm^3/coul		6850	6270	5930	4400	----
μ cm^2/volt sec.		2600	2670	3150	2550	----
n no./cm^3 x 10^{15}		1.07	1.17	1.24	1.69	----

Table 2

EVALUATION SUMMARY OF CELLS FABRICATED FROM INGOT NO. B125

		Test Cell Vacuum 15 Microns of Hg									
Wafer #	Cell #	$D^* \times 10^9$ $\frac{cm(cps)^{1/2}}{watt}$	Detector Resistance ohms x 10^3	Load Resistance ohms x 10^3	Bias Current µA	Bias Potential volts	Signal µV	Noise µV	Resistance at 300°K R_{300} ohms	Resistance at 77°K R_{77} ohms x 10^3	Ratio R_{77}/R_{300} x 10^3
2	1	1.3	120	1000	36	3.3	47	.29	3.0	240	80
	2	No Signal									
3	1	1.65	100	1000	73	7.3	94	.29	3.0	280	94
	2	1.54	80	100	335	27.	288	.93	3.0	240	80
4	1	1.50	100	100	300	30.	370	1.24	3.0	240	80
6	1	No Signal									
	2	No Signal									
	3	1.67	90	1000	73	6.6	73	.22	3.0	180	60
	4	1.50	80	1000	74	5.9	84	.28	2.8	125	45
7	1	1.73	140	1000	70	9.7	165	.48	2.8	260	93
	2	1.23	100	1000	72	7.2	94	.38	2.2	260	120
8	1	1.05	100	1000	72	7.2	92	.44	2.8	280	100
	2	1.25	100	1000	54	5.4	72	.29	2.8	280	100
9	1	Broken in Test									
	2	Broken in Test									
	3	1.19	75	100	453	34.	332	1.4	2.4	200	83
	4	Noisy									
10	1	1.18	85	1000	73	6.2	147	.44	2.6	77	73
	2	Broken									
	3	1.31	220	1000	63	13.9	134	.51	3.0	167	63
12	1	1.15	80	1000	74	5.7	84	.37	2.4	170	71
	2	0.70	70	100	118	8.2	130	.87	2.4	160	67
13	1	0.97	120	1000	71	8.5	96	.49	2.6	200	77
	2	1.70	80	1000	74	5.9	88	.26	2.4	160	67
15	1	1.43	120	1000	53	6.4	96	.34	2.0	200	100
	2	1.14	75	1000	73	5.5	52	.23	2.2	220	100

Table 3

PARAMETER MEASUREMENTS - INGOT B128

Supplier: Eagle Picher
Ingot Weight: 443 g
Dopant Amounts: Au 4.43 g
Sb 0.42 mg

No. of Passes: 25
Avg. Resistivity: 40^+ ohm-cm

Date: 3/28/63
Orientation: <111>

Wafer No. →		1	4	8	12	16	20	24
ρ at 300°K ohm-cm	1	2.1	2.8	2.0	1.5	1.3	1.00	0.57
	2	2.3	2.2	1.8	1.5	1.2	0.73	0.68
	M	2.1	2.0	1.7	1.3	1.0	1.00	0.45
	3	2.1	2.2	1.9	1.5	1.4	1.10	0.20
	4	2.3	2.3	1.8	1.4	1.2	0.87	0.47
Dislocation Density no./cm^2 x 10^3		11.8	12.0	14.0	very high	very high	very high	gold precip.
Cooling Ratios x 10^3	1	127	100	150	99	216	97	163
	2	96	117	155	--	187	274	---
Hall Measurements at 300°K								
ρ ohm-cm		2.08	----	1.71	1.40	1.12	0.85	----
R_H cm^3/coul		5680	----	4370	3490	2800	2460	----
μ cm^2/volt sec.		2730	----	2560	2500	2500	2880	----
n no./cm^3 x 10^{15}		1.3	----	1.58	2.11	2.63	3.00	----

Table 4

EVALUATION SUMMARY OF CELLS FABRICATED FROM INGOT NO. B128

		Test Cell Vacuum 15 Microns of Hg									
Wafer #	Cell #	$D^* \times 10^9$ $\frac{cm(cps)^{1/2}}{watt}$	Detector Resistance ohms x 10^3	Load Resistance ohms x 10^3	Bias Current μA	Bias Potential volts	Signal μV	Noise μV	Resistance at 300°K R_{300} ohms	Resistance at 77°K R_{77} ohms x 10^3	Ratio R_{77}/R_{300} x 10^3
2	1	1.55	100	1000	54	5.4	75	.24	3.0	300	100
3	1	1.28	70	1000	56	3.9	38	.15	2.8	240	85
	2	1.20	240	1000	64	15.3	136	.57	7.0	600	85
	3	1.10	100	1000	73	7.3	204	.92	2.4	280	117
4	1	1.29	85	100	430	43.0	296	1.20	2.8	350	125
	2	1.15	140	1000	70	9.8	89	.39	2.8	350	125
5	1	1.23	120	1000	53	6.4	83	.34	3.0	350	117
	2	0.65	100	1000	54	5.4	88	.68	2.6	300	115
9	1	1.20	150	1000	69	10.3	138	.57	2.4	320	130
11	1	1.80	120	1000	36	4.3	105	.29	2.4	340	140
	2	1.30	100	1000	73	7.3	68	.26	2.4	440	180
13	1	1.45	180	1000	68	12.0	160	.53	1.8	340	190
	2	0.95	80	1000	74	5.9	50	.26	2.0	320	160
15	1	1.35	120	1000	71	8.5	97	.36	1.4	340	240
17	1	1.06	100	1000	72	7.2	66	.31	1.4	280	200

Table 5

PARAMETER MEASUREMENTS - INGOT B129

Supplier: Rare Metals
Ingot Weight: 442 g
Dopant Amounts: Au 4.42 g
Sb 0.43 mg

No. of Passes: None
Avg. Resistivity: 40 ohm-cm

Date: 5/17/63
Orientation: <111>

Wafer No. →		1	5	10	15	20	25	30
ρ at 300°K ohm-cm	1	2.24	2.12	1.89	1.63	1.37	0.70	0.56
	2	2.38	2.20	1.99	1.71	1.30	0.76	0.60
	M	2.12	2.02	1.83	1.60	1.38	1.06	0.71
	3	2.26	2.09	1.87	1.64	1.40	0.68	0.63
	4	2.44	2.52	2.26	1.85	1.38	0.81	0.73
Dislocation Density no./cm^2 x 10^3		5.45	10.9	8.15	9.90	very high	gold precip.	gold precip.
Cooling Ratios x 10^3	1	84.5	64	107	140	193	193	126
	2	83.5	64	109	159	208	175	132
Hall Measurements at 300°K								
ρ ohm-cm		2.64	2.40	2.25	1.82	----	----	----
R_H cm^3/coul		7400	6460	6130	4880	----	----	----
μ cm^2/volt sec.		2800	2680	2730	2690	----	----	----
n no./cm^3 x 10^{15}		1.00	1.14	1.19	1.51	----	----	----

Table 6

EVALUATION SUMMARY OF CELLS FABRICATED FROM INGOT NO. B129

Wafer #	Cell #	Test Cell Vacuum 15 Microns of Hg: $D^* \times 10^9$ $\frac{cm(cps)^{1/2}}{watt}$	Detector Resistance ohms $\times 10^3$	Load Resistance ohms $\times 10^3$	Bias Current μA	Bias Potential volts	Signal μV	Noise μV	Resistance at 300°K R_{300} ohms	Resistance at 77°K R_{77} ohms $\times 10^3$	Ratio R_{77}/R_{300} $\times 10^3$
2	1	1.00	140	1000	70	9.8	188	.93	3.0	280	93
	2	No Signal									
	3	1.05	95	1000	73	6.9	87	.41	2.8	200	71
	4	1.05	125	1000	53	6.6	52	.25	2.8	240	86
3	1	1.11	85	1000	73	6.2	87	.39	2.6	200	77
	2	1.14	80	1000	74	5.9	86	.30	2.4	180	75
4	1	1.69	75	100	230	17.2	202	.60	2.6	140	54
	2	1.75	95	100	410	39.0	506	1.44	2.8	240	86
6	1	2.35	140	1000	70	9.8	270	.57	2.6	140	54
7	1	1.15	75	1000	74	5.6	80	.35	2.6	140	100
	2	2.04	140	1000	70	9.8	176	.43	2.6	280	108
	3	1.38	95	1000	73	6.9	79	.28	2.8	260	93
9	1	1.83	130	1000	71	9.1	125	.34	2.4	240	100
	2	0.92	100	100	400	40.	220	1.20	2.2	240	109
11	1	2.50	120	100	272	33.	550	1.10	2.4	240	100
	2	1.00	85	1000	74	6.3	113	.56	2.8	150	54
13	1	1.30	95	1000	73	6.9	91	.35	2.6	260	100
14	1	1.45	150	1000	70	11.	167	.58	2.4	380	160
	2	1.63	140	1000	53	7.4	89	.27	2.2	400	180
16	1	1.30	150	1000	52	7.8	90	.34	2.4	350	145
	2	1.56	130	1000	71	9.	140	.45	2.2	360	163

Table 7

PARAMETER MEASUREMENTS - INGOT B139

Supplier: Rare Metals
Ingot Weight: 457 g
Dopant Amounts: Au 2.68 g
Sb 0.28 mg

No. of Passes: None
Avg. Resistivity: 40+ ohm-cm

Date: 5/17/63
Orientation: <111>

Wafer No. →		1	6	11	16	21
ρ at 300°K ohm-cm	1	3.86	3.30	2.74	1.43	1.31
	2	3.78	3.25	2.78	1.52	1.08
	M	3.68	3.23	2.78	1.82	1.17
	3	3.78	3.20	2.73	1.62	1.05
	4	3.84	3.28	2.70	1.81	1.02
Dislocation Density no./cm^2 x 10^3		7.6	5.2	11.6	gold precip.	poly-crystalline
Cooling Ratios x 10^3	1	21.2	43	40	42	2
	2	25	82	36	35	
Hall Measurements at 300°K						
ρ ohm-cm		4.08	3.09	2.70	1.65	1.32
R_H cm^3/coul		9750	8540	6920	4560	3160
μ cm^2/volt sec.		2390	2760	2560	2760	2390
n no./cm^3 x 10^{15}		.76	.86	1.06	1.62	2.33

Table 8

EVALUATION SUMMARY OF CELLS FABRICATED FROM INGOT NO. B139

		Test Cell Vacuum 15 Microns of Hg									
Wafer #	Cell #	$D^* \times 10^9$ $\frac{cm(cps)^{1/2}}{watt}$	Detector Resistance ohms $\times 10^3$	Load Resistance ohms $\times 10^3$	Bias Current µA	Bias Potential volts	Signal µV	Noise µV	Resistance at 300°K R_{300} ohms	Resistance at 77°K R_{77} ohms $\times 10^3$	Ratio R_{77}/R_{300} $\times 10^3$
2	1	1.98	55	1000	38	2.1	184	.46	2.6	160	61
	2	1.90	30	100	310	9.1	170	.44	2.2	100	45
	3	2.08	55	100	390	21.	260	.63	2.2	135	61
	4	1.80	50	1000	76	3.8	270	.76	3.2	140	44
	5	1.28	50	1000	76	1.9	190	.73	3.4	150	44
7	1	1.50	40	100	290	12.5	250	.84	4.2	110	26
	2	1.90	55	100	390	21.	290	.78	4.2	130	32
12	1	1.95	40	100	290	11.	190	.56	2.8	120	43
	2	1.48	40	100	290	11.	180	.62	3.0	150	50
	5	1.50	50	100	270	13.	225	.75	2.4	140	59
17	1	1.75	65	100	270	18.	530	1.50	2.2	135	61
	4	1.70	45	100	270	12	210	.61	3.8	130	34

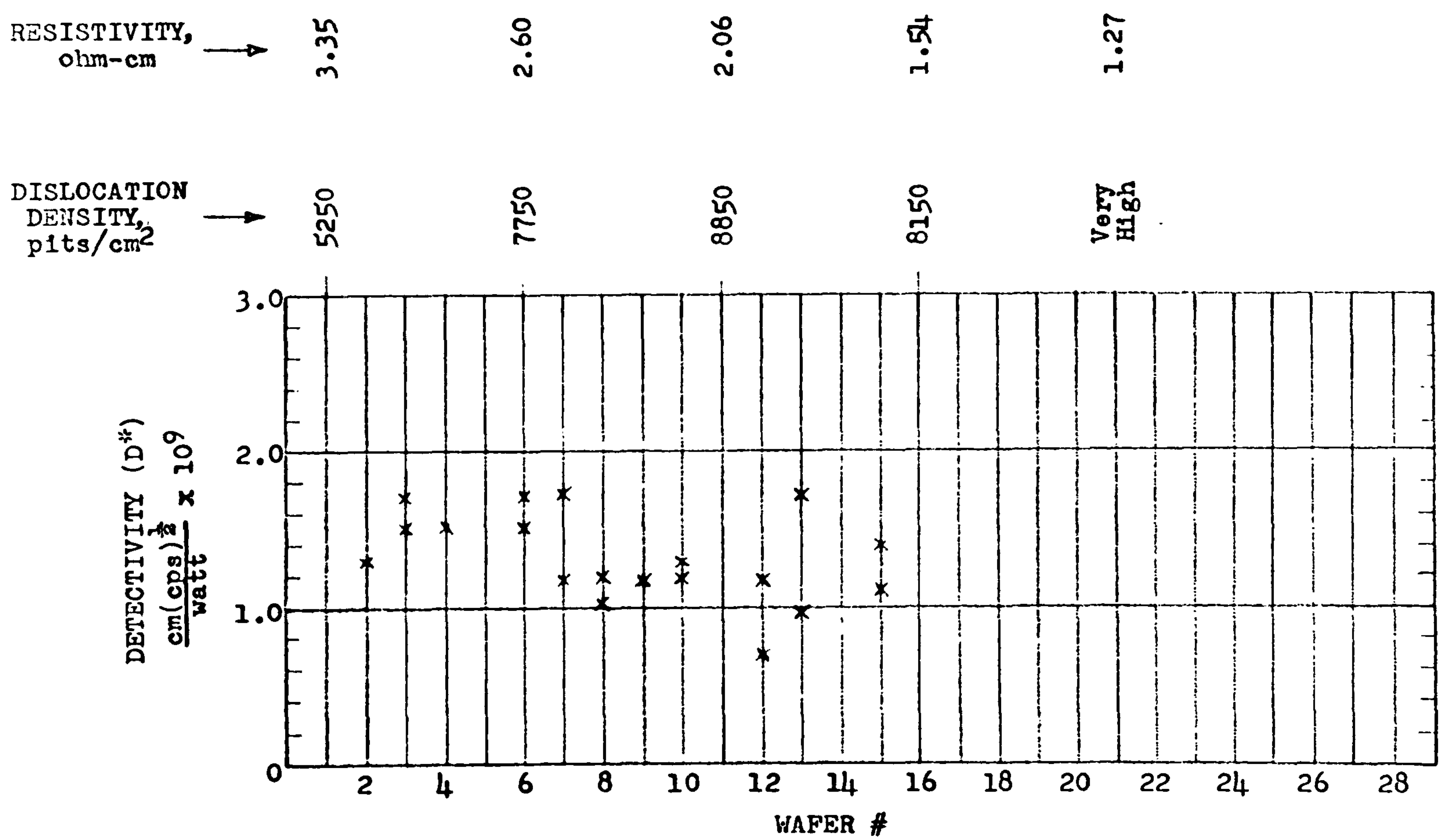


Figure 1. Graphic presentation of evaluation data - Ingot No. B125

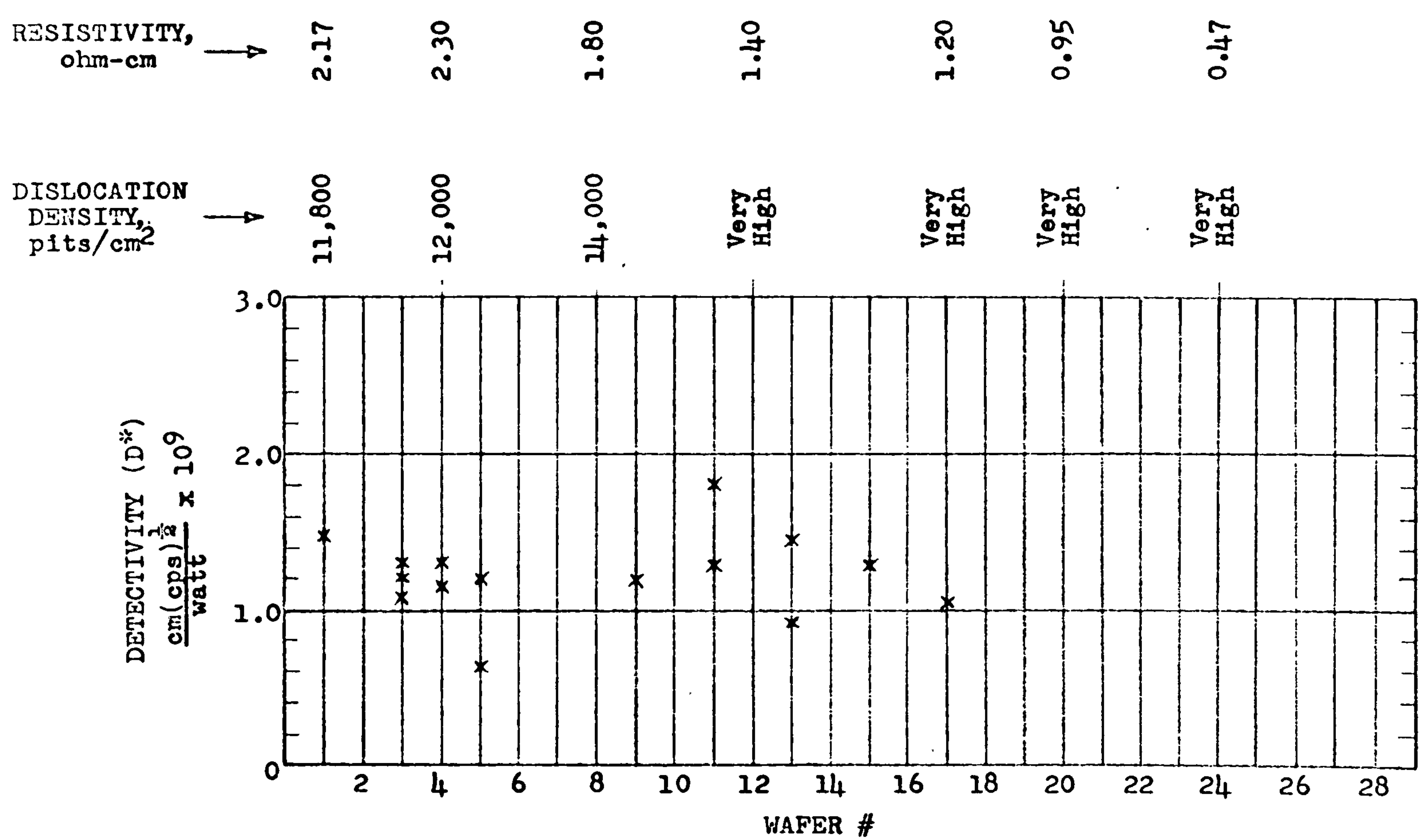


Figure 2. Graphic presentation of evaluation data - Ingot No. B128

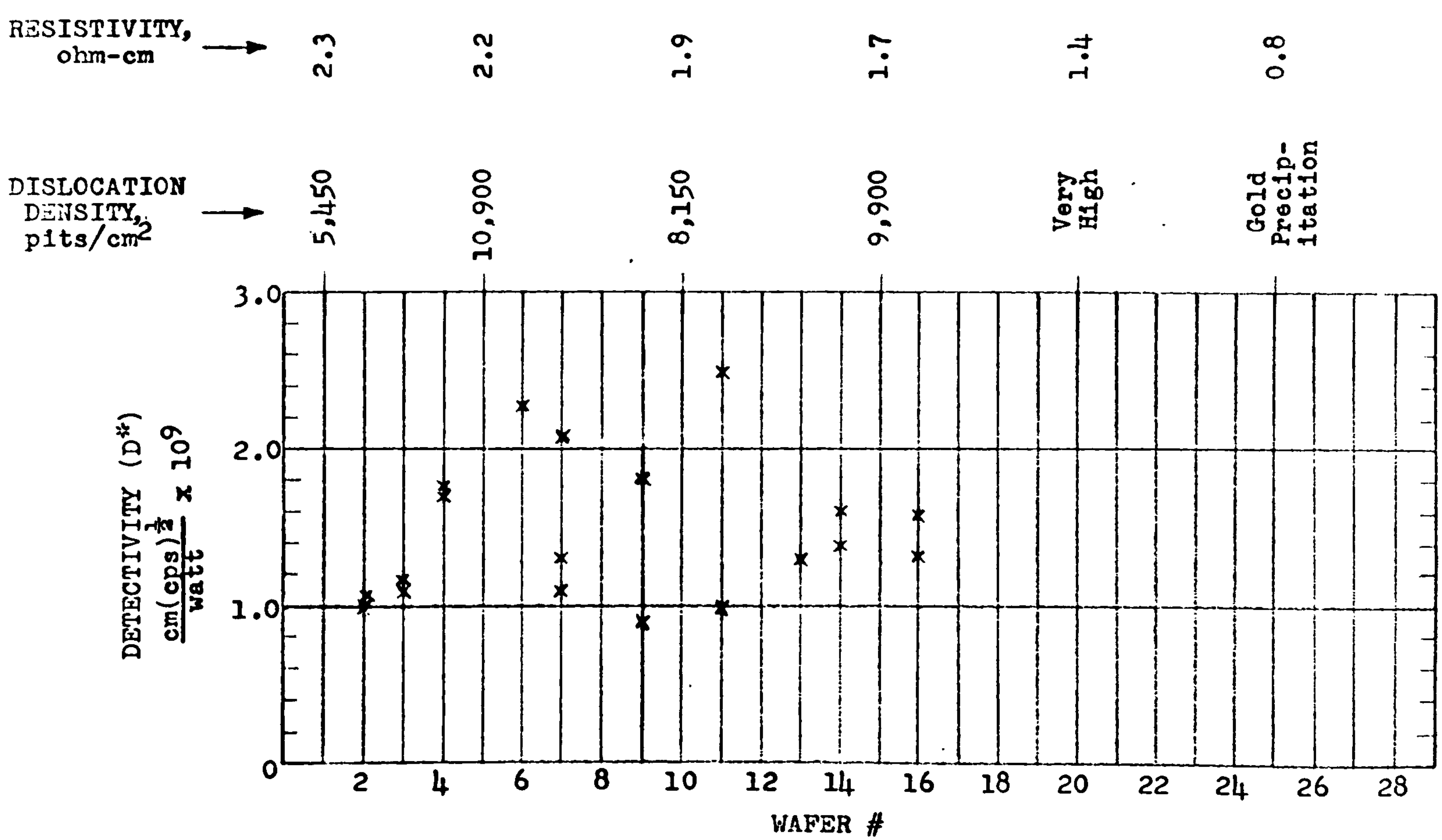


Figure 3. Graphic presentation of evaluation data - Ingot No. B129

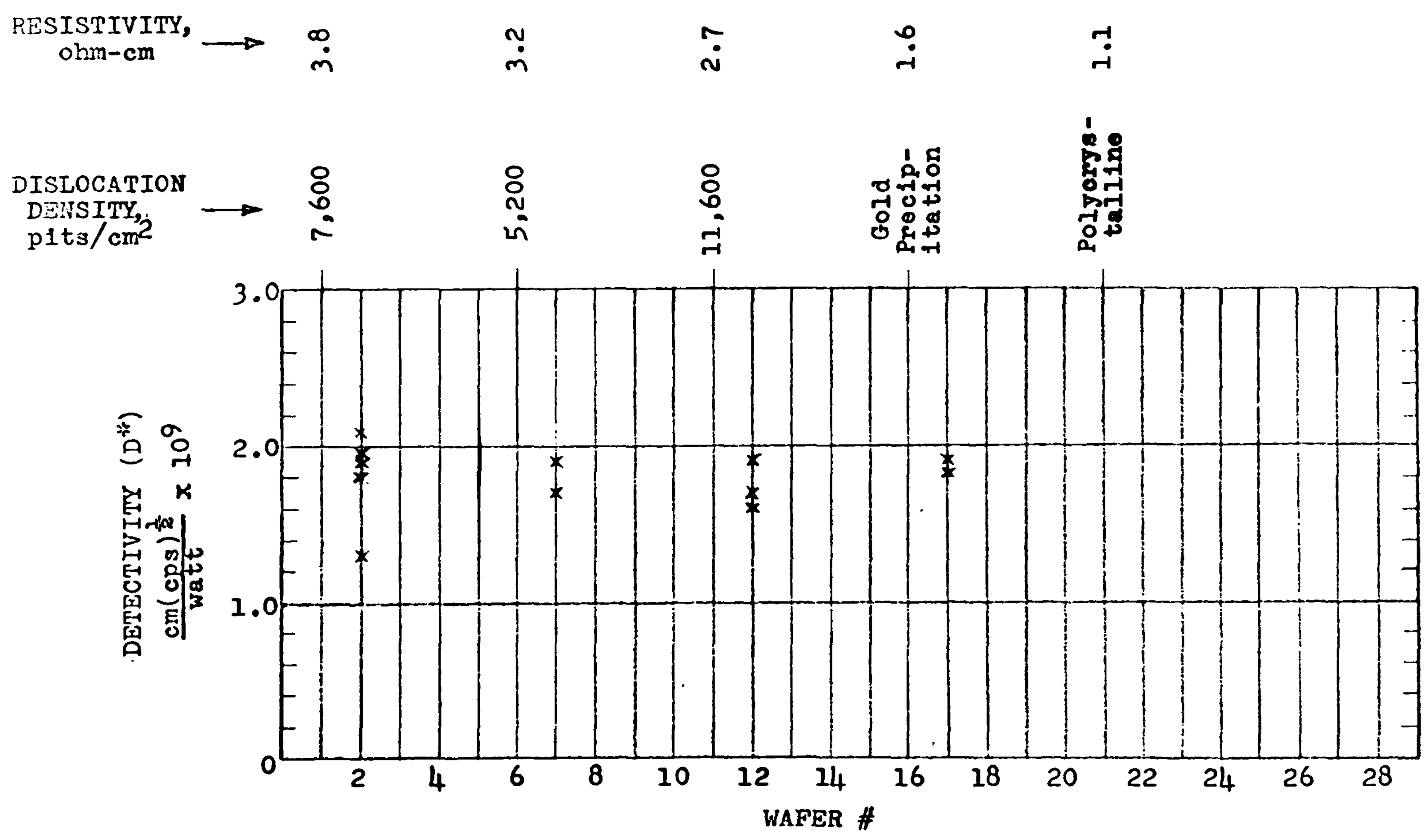


Figure 4. Graphic presentation of evaluation data - Ingot B139

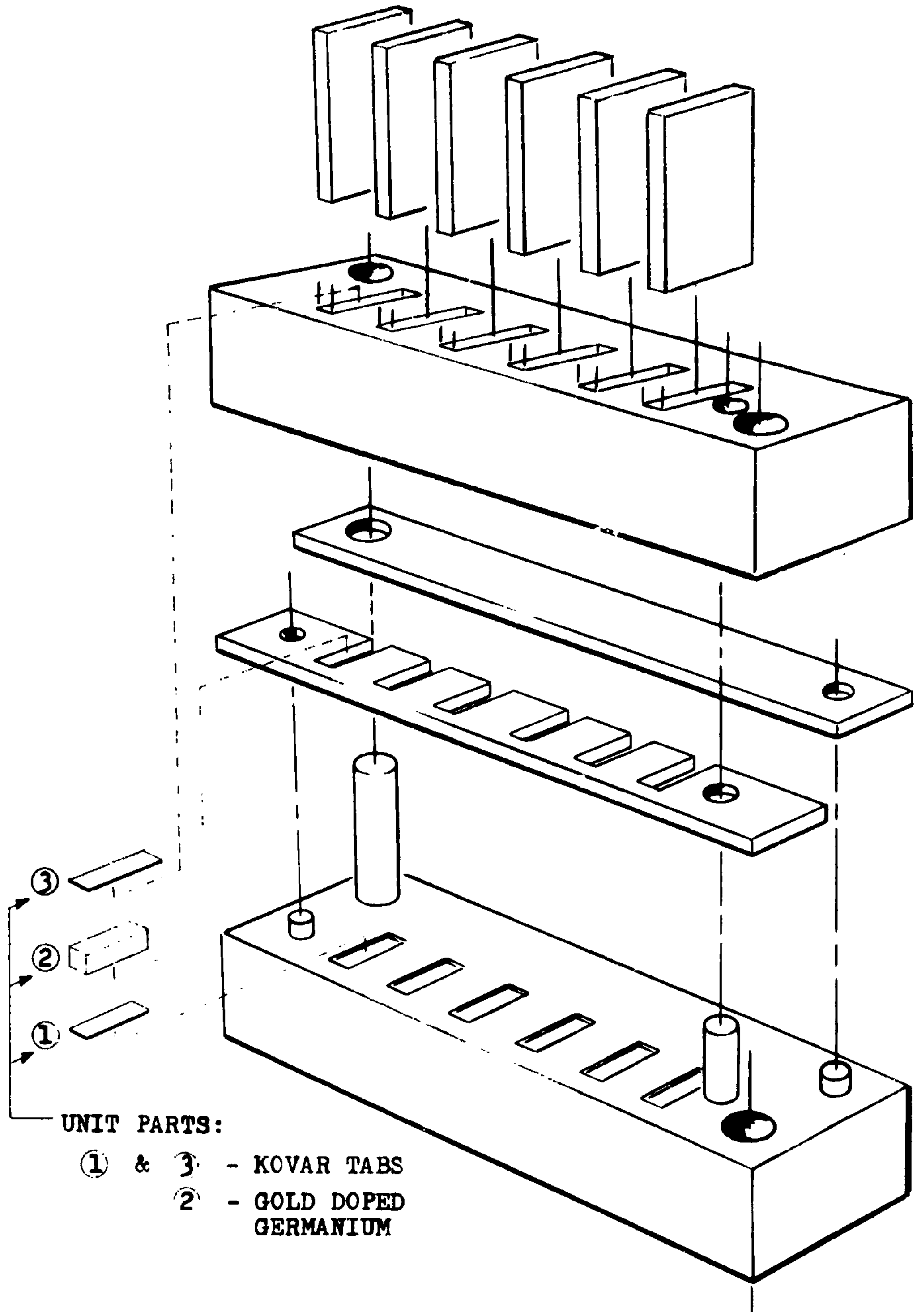
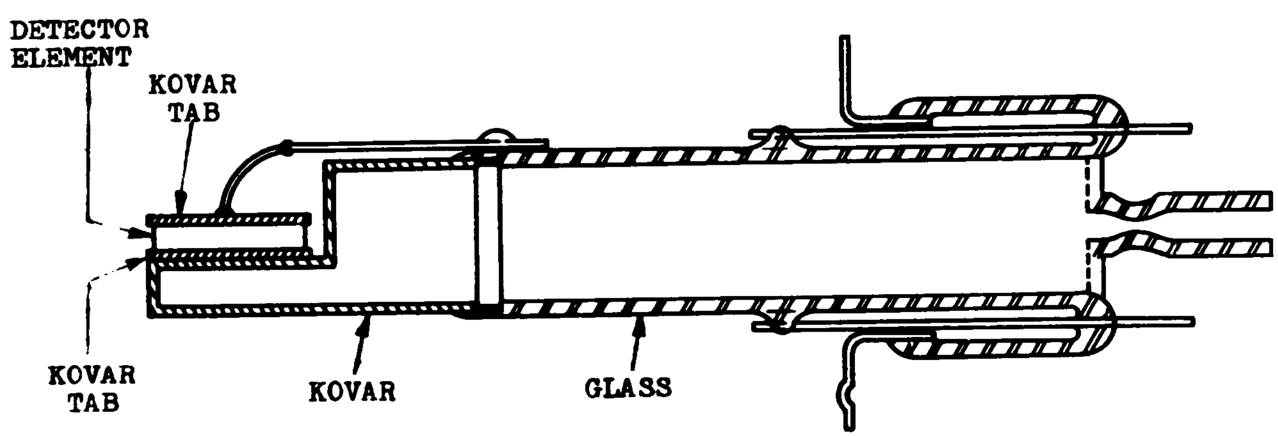


Figure 5. Carbon alloy boat, showing sequence of loading unit parts



Scale - 2:1

Figure 6. Demountable dewar inner assembly

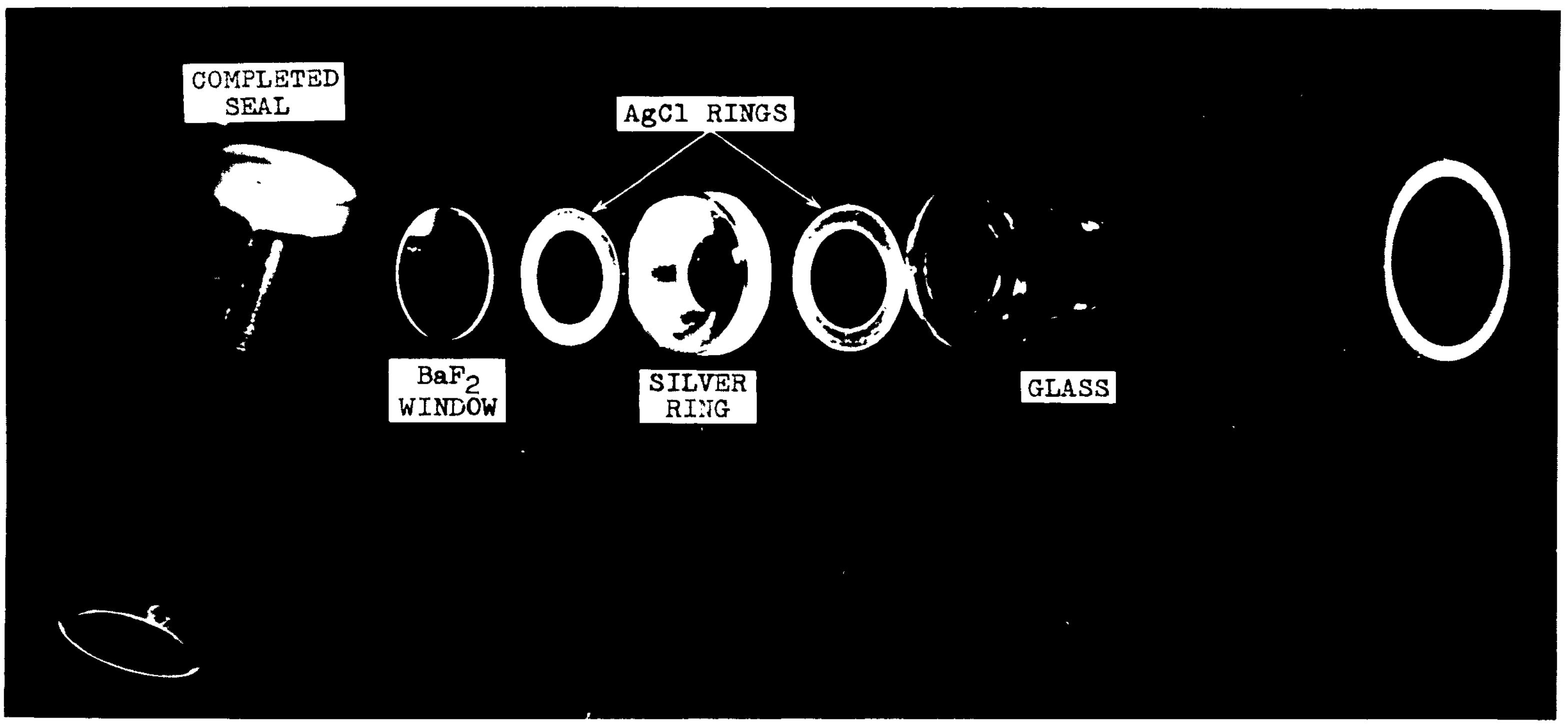


Figure 7. Components of and completed BaF_2 window seal